GROWTH, AGE AND NATURAL MORTALITY OF *NOTOTHENIA ROSSII ROSSII* IN THE KERGUELEN ISLANDS AREA

by

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ABSTRACT. - Dynamics of age-length structure of the Kerguelen Islands population of *Notothenia rossii rossii* is presented on the basis of data available for the 1970-1984 period. Growth rate, calculated by scales reading for the beginning of exploitation and later, when the structure of fish population has changed as a result of exploitation, is similar in values when compared. Quantitative estimates of growth parameters were obtained using von Bertalanffy's equations and agree, in general, with data of other authors. Natural mortality coefficient for the Kerguelen population of *Notothenia rossii rossii* was determined applying three independant methods.

RÉSUMÉ. - L'évolution de la structure démographique de la population exploitée de *Notothenia rossii rossii* des îles Kerguelen est présentée à partir des données disponibles pour la période 1970-1984. Les taux de croissance entre le début de l'exploitation et après des changements de structure de la population liés à la pêche sont comparés à l'aide des résultats de lecture de l'âge sur les écailles et fournissent des valeurs similaires. Les estimations quantitatives des paramètres de croissance de l'équation de Von Bertalanffy concordent, en général, avec les données d'autres auteurs. Le coefficient de mortalité naturelle pour la population de *Notothenia rossii rossii* des îles Kerguelen a été estimé par trois méthodes indépendantes.

Key-words: Nototheniidae, *Notothenia rossii*, Kerguelen Islands, Length, Growth, Age, Natural mortality.

Marbled notothenia, *Notothenia rossii* Richardson, inhabits shelf waters of antarctic and subantarctic islands, and also adjacent seamounts. The species forms commercial concentrations on the shelf of the Kerguelen islands (Indian sector of the Southern ocean) and in the area of South Georgia (Atlantic sector), comprising a considerable part in the catches in the early 70s.

Knowledge on growth characteristics and age structure is of great practical importance for choosing optimum fishing policy. At the present, most of the published articles on growth and age of this species concern South Atlantic subspecies: *Notothenia rossii marmorata* (Olsen, 1954; Shcherbich, 1975, 1976; Slinst and Pinskaya, 1978; Freytag, 1980; Burchett, 1983).

Analogous data on the Indian sector subspecies: *Notothenia rossii rossii* are restricted at the Kerguelen area to works by Hureau (1970) and Duhamel (1987). Hureau determined the age of young fish (down to 5 years old), inhabiting inshore waters of the island. Duhamel's data described mature fish for the period from 1980 to 1987. Data on age-length composition of catches from the commercially

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exploited size groups from the beginning of the fishery 1970 to 1980 are absent from literature.

This paper fill the gap in knowledge about these parameters for mature *N. rossii rossii* at the Kerguelen Islands.

MATERIAL AND METHODS

The study is based on materials collected during winter-spring period (June-November) by research and fishing vessels in the Kerguelen islands area in 1969-1984. Research fishing was conducted by commercial trawls, which were also used by commercial fishing vessels.

Fish were measured in total length (TL) (with a 5 cm interval). More than 22 000 specimens were measured and weighted.

Age of 902 specimens of *N. rossii rossii* was determined by the analysis of scales. Number of age determinations by years is presented in the Table I. Age composition of catches for the years when scale sampling was unavailable, was determined by the nearest year, when these determinations were made.

Annual growth increment was considered to complete by the beginning of Austral winter. Growth zones of fish older than 10 years are located on the edge of scale and these zones are often destroyed, which makes age determination of these fish difficult. Doubtful samples were discarded.

While determining the age, attention was paid to the variations in the first ring formation, in the manner described by Shcherbich (1975). Age of specimens, having 45-68 sclerites before the first distinct annual check on scales was determined by adding one year to a number of well-defined annual checks. If the first winter growth mark coincided with 201-25 sclerites, then age was recorded as corresponding with the number of visible annual checks. Absolute estimates, obtained through direct observations were used to determine growth characteristics. Parameters of von Bertalanffy's growth equation were calculated after Hohendorf's (1966) methods.

Three independent methods were used to determine natural mortality coefficient. The integral method of Beverton and Holt (1956) when the stock is virgin where Z, total mortality coefficient equal M, natural mortality coefficient in the equation: $Z = M = K (L\infty - \bar{L}) \bar{L} - L'$

The second method is the Rikhter and Efanov's equation (1976) where the natural mortality coefficient is related to age tn, the age at which more than 50% of fish mature for the first time. In methodical recommendations by VNIRO (Babayan *et al.*, 1984) it is specified that tn is the age when 70% of fish mature for the first time. Finally the natural mortality coefficient was also determined after the

Table I: Number of specimens of *Notothenia rossii rossii* used for the age determination. Length of fish was measured to the nearest 0.1 cm.

Years	Length (cm)													Total
	25	30	35	40	45	50	55	60	65	70	75	80	85	
1969/70			1	9	20	64	72	56	58	20	1	2		305
1971					1	3	5	18	21	4	4			56
1972			9	34	15	9	3	4	6	5	4	1		90
1974			4	11	11	11	11	12	15	13	10	3		101
1980	5	11	15	18	11	9	10	11	3	3				89
1981			2	12	11	13	11	14	10	9				89
1982	3	6	16	12	16	15	7	7	3					80
1984	3	1	10	11	12	12	12	14	6	7	4			92
Total	11	31	94	81	93	110	133	136	119	57	15	2		902

method of Heincke (1913) used by Convention for Conservation of Antarctic Marine Living Resources (CCAMLR) with the formula:

$$M(=Z) = \frac{\ln (N_a + N_{a+1} + N_{a+2} + \ldots)}{N_{a+1} + N_{a+2} + \ldots}$$

RESULTS

Age-length composition of catches

Length composition of the exploited part of population from the beginning of exploitation to 1984 is presented in Fig. 1. Before 1972 specimens 55-70 cm in length comprised the majority of the catches (73.5%), with a mean length 62.0-64.5 cm. Maximum length and weight, registered in our catches were 87 cm and 9 kg respectively. During the following years the mean length of *N. rossii rossii* gradually decreased. Thus in 1980-82 and in 1984 the majority of the specimens in the catches were 40-60 cm in length with a mean length value down to 53.4 cm.

According to this data, the exploited part of the population consisted of fish aged 3-14 years. Older specimens were probably also present in the catches (80 cm and more) but they were very rare. Immature fish down to two years old were not present in trawl catches beyond territorial waters where the fishing and research vessels operated, and fish of the third age-group were present in small quantities (0.3-3.7%) in the trawlable areas for the vessels. At the beginning of exploitation the majority of catches was formed by fish aged 7-10 years. One should note that fish, spawning for the first time were determined as being 5.3 year-old and 5.8 year-old (males and females respectively). Their age was determined by the first, sharply shrunk growth zone in the manner described by Shcherbich (1975). Fish aged 4-8 years prevailed in catches in 1980-1984, and older specimens (older than 9 years) made up 4% of the total catch of *N. rossii rossii*.

Growth in length and weight

The maximum increase in length (from 9.4 to 15.2 cm) of *N. rossii rossii* takes place during the first three years of life (Table II). After which the rate of growth reduces (down to 6.0- 7.4 cm per year), related to maturation. Some males of the Kerguelen *N. rossii rossii* mature for the first time at 39 cm in length, aged 4

Table II: Length and weight for age groups of *Notothenia rossii rossii*. The values in brackets were obtained by extrapolation.

Age groups	Measured length (cm)	Gain (cm)	Measured weight (g)	Gain (g)	n	Measured length (cm) females	Measured length (cm) males
I		(12.5)		(68)			
II		(10.9)		(1591			
III	31.9	19.41	487	269	39	32.1	31.0
IV	39.3	7.4	830	343	126	38.7	40.2
V	46.3	7.0	1335	505	120	45.8	46.2
VI	52.3	6.0	1984	649	133	54.2	51.2
VII	56.1	4.4	2475	491	120	56,8	56,1
VIII	61.6	4.9	3170	695	147	60,8	61,9
IX	65.6	4.0	3958	788	93	65,7	65.1
X	68.9	3.3	4411	453	68	68,8	68.5
XI	72.1	3,2	5151	740	29	72.5	71.5
XII	75.1	3.6	5310	159	17	75.7	
XIII	77.7	2.0	5500	190	6	77.7	
XIV	78,5	0,8	5570	70	4	78.5	

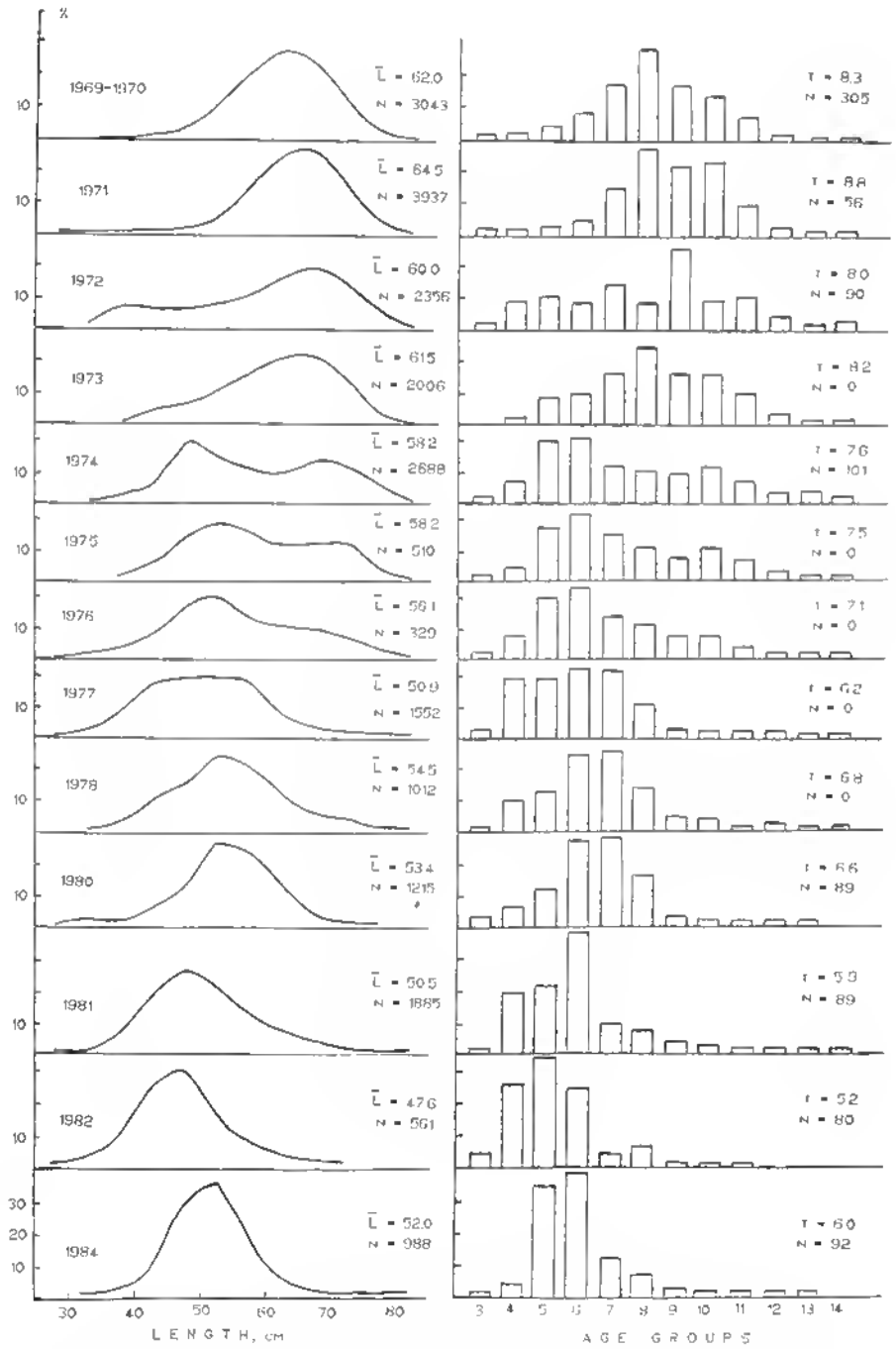

Fig. 1: Age-length composition of catches of *Notothenia rossii rossii* at the shelf of the Kerguelen Islands. L̄ : mean length; T: mean age; N: number of specimens used for length and age distributions.

years, and 50% of males mature for the first time at 41.2 cm in length. Females mature later, with 50% mature females at 48.0 cm in length. Growth rates of males somewhat reduce in comparison with females after maturation (Table II). Minimal increments in length were registered in fish older than 10 years.

Increments in weight were relatively small (70-270 g) during the first three years. Weight increased considerably with the onset of maturation, attaining maximum values for 6-9 year-old fish (Table II). Note that the weight of ripe gonads of *N. rossii rossii* (stage IV after Everson maturity scale) is 600-1000 g on the average. Maximum weight increase for mature fish was not only related to an increase in body weight, but also to considerable increase in the weight of gonads. After this, the rates of weight gain in older age groups (over 10 years) decreased which is related to the processes of ageing.

We attempted to calculate the differences in growth rates of *N. rossii rossii* for the period of maximum numbers of population (1969-1972) and for the period, when the stock was reduced considerably (1980-1982). Comparison of growth in length and weight produced similar values (Table III).

Evaluation of growth parameters

Ratio between length of fish and its weight is approximated by an equation $W = aL^b$ exp. b, and its parameters were calculated separately for males and females for the July-August period:

males $W_1 = 0.0231\ L^{2.85}$ exp. 2.85 n = 269

females $W_1 = 0.0213\ L^{2.88}$ exp. 2.88 n = 330

It is clear from the equations derived that sex has only a small influence on the "length-weight" ratio. That is why the following ratio without division by sex was used for calculations:

$W_1 = 0.0215\ L^{2.87}$ exp. 2.87 n = 599

Data from determination of age-length catch composition of *N. rossii rossii* on the Kerguelen islands shelf for 1980-1982 period were used for quantitative evaluation of growth parameters (Table IV). The values obtained agree rather well with data from other sources for *N. rossii* from South Georgia and other data from the Kerguelen Islands (Olsen, 1954; Hureau, 1970; Shcherbich and Slepokurov, 1976; Shust and Pinskaya, 1978; Freytag, 1980, Burchett, 1983; Duhamel, 1987). Study of growth and analysis of the values obtained by von Bertalanffy's equation show that *N. rossii* reaches 70% on its maximum weight by the age of 9.

Table 10: Observed values of length and weight at age for two periods in *Notothenia rossii rossii*.

Age groups	1969 - 1972			1980 - 1982		
	Length (cm)	Weight (g)	n	Length (cm)	Weight (g)	n
III	33.1	576	6	31.9	457	26
IV	39.1	866	39	39.6	878	58
V	47.1	1319	44	46.1	1349	42
VI	52.6	2024	50	52.1	1953	53
VII	56.6	2540	79	56.7	2266	22
VIII	61.3	3239	95	62.0	2971	26
IX	65.4	3975	66	66.4	3894	13
X	68.8	4452	43	68.9	4300	11
XI	72.0	5199	19	73.5	4863	3
XII	67.0	4760	5	74.5	5392	5
XIII	79.0	5600	?	76.5	5400	2
XIV	79.0	5370	?			

Table IV: Values of parameters of the Von Bertalanffy growth formula for *Notothenia rossii rossii*.

Area of investigation	Sex	Von Bertalanffy's parameters L_∞ (cm)	W_∞ (g)	K	t_o	Authors
South Georgia	male	88.2		0.119	0.1060	Olsen, 1954
	female	97.1		0.108	0.028	
"	both	91.5	9000	0.16	0.4	Shcherbich and Slepokurov, 1976
"	male	80.6	10253	0.188	0.198	Shust and Plonkaya, 1978
	female	80.1	10025	0.200	0.296	
"	both	97.2	11025	0.107	-0.007	Treytag, 1980
"	both	125.5		0.067	-0.589	Burchett, 1983
Kerguelen	juv.+ male	80.0		0.13	-1.69	Duhamel, 1978
	juv.+ fem.	90.0		0.13	-0.62	
"	male	80.7		0.180	0.861	Duhamel, 1987
	female	89.2		0.152	0.757	
"	both	104.0	12270	0.102	-0.79	present study

Theoretically possible duration of life (T) was calculated using the formula:

$$T = 1.n1.\infty - 1.n(1.\infty - 1.max)/K = 17,8$$

where Lmax = maximum length of fish in catches (87 cm).

Thus the estimated longevity for *N. rossii rossii* from the Kerguelen Islands was 17-18 years. Specimens, larger than 75-80 cm were present even at the beginning of exploitation only very rarely which indicates high natural mortality of these fish.

Natural mortality

From analysis of length composition of *N. rossii rossii* in 1971 catches (the first year of intensive fishing with a report of 149 700 tonnes) L_c = 64.52 cm and L_c' = 50 cm. Von Bertalanffy's growth equation parameters were calculated for fish aged 3-14. The following values were obtained: L_∞ = 104 cm; K = 0.102. Inserting the values into the equation of Beverton and Holt (1956) we obtain the value of M = 0.28 (Table V).

Table V: Estimates of the exponential coefficient of natural mortality (M) for *Notothenia rossii rossii* obtained by different methods.

Area of investigation	Method used	Age groups investigated (years)	M values	Authors
South Georgia	Beverton and Holt	10 - 16	0.38	Shcherbich and Slepokurov, 1976
"	"	1 - 4	0.78	Burchett and Ricketts, 1984
	"	6 - 9	0.35	
	"	11 - 16	0.65	
"	"		0.2	Kock, 1985
Kerguelen	"	1 - 12	0.25	Kock et al., 1985
	Rikhter and Efanov		0.24	
	Pauly		0.13	
"	Beverton and Holt	3 - 14	0.28	present study
	Rikhter and Efanov	3 - 14	0.32	
	Heincke	3 - 14	0.39	

According to Rikhter and Efanov's equation (1976) the tr value for *N. rossii rossii* (70% of mature fish) is 5 years. So, inserting the value obtained the natural mortality coefficient, M = 0.32.

Out of the analysis of catch curve of *N. rossii rossii* for 1971, obtained by direct summing (Sparre, 1989) the natural mortality coefficient from the Heincke's method (1913), M = 0.39.

DISCUSSION

According to this data in trawls, the length of specimens of *N. rossii rossii* from the exploited part of the Kerguelen islands population varied from 26.5 to 87 cm with maximum weight of 9 kg. According to Duhamel (1982) maximum length and weight of this species on the shelf of the Kerguelen Islands were 90 cm and 10 kg respectively in July 1981.

The most probable reason of the first annual mark formation of the South Atlantic subspecies, according to Shcherbich (1975), is the change in the character of habitat and feeding, related to the transition of alevins from the pelagic to the near-bottom mode of life. Taking into account similar biological features of the both subspecies, their life cycles (Duhamel, 1987), time of spawning and hatching, the probable reason of the first annual mark formation in *N. rossii rossii* from Kerguelen islands is also the transition.

The data obtained indicate that the growth rate of *N. rossii rossii* is close to the results, obtained earlier by Shcherbich (1976) and Shust and Pinskaya (1978) for the South Atlantic sub-species. Deviation from the data of Hureau (1970) for immature specimens of *N. rossii rossii* from Kerguelen Islands area may be due to some methodological differences.

As a result of investigations it was stated that duration of life of males of *N. rossii rossii* from the Kerguelen area, as well as that of South Atlantic subspecies is rather less than that for females. Number of males decreases considerably from age 10, and starting from age 11-12 they are practically absent from the catches. Note that females had maximum length and weight, and were more numerous in older age-groups than males, which was also registered by Duhamel (1987).

Published data on natural mortality are rather controversial (Table IV). Thus, values of M for *N. rossii marmorata* from South Georgia area (except data for immature fish aged 1-4) are within 0.20-0.65 range. Minimal value was obtained by Kock (1985) for South Atlantic subspecies.

As for *N. rossii rossii* from the Kerguelen Islands Kock *et al.* (1985) evaluated M as 0.13-0.25. However, they analysed materials, collected from the specimens aged 1-12. Probably this may explain the existing difference in determining natural mortality coefficient. Finally, it is doubtful whether Pauly's method (1980) can be applied for determination of natural mortality coefficient of Antarctic fish like *N. rossii rossii*. Empiric method with ambient temperature was developed by Pauly for tropical and temperate water fish, whose metabolic rate is higher, and it has yet to be appropriate for species from high latitudes.

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